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# The Future of Nuclear Power: Value Orientations and Risk Perception

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Since the turn of the 21st century, there has been a revival of interest in nuclear power. Two decades ago, the expansion of nuclear power in the United States was halted by widespread public opposition as well as rising costs and less than projected increases in demand for electricity. Can the renewed enthusiasm for nuclear power overcome its history of public resistance that has persisted for decades? We propose that attitudes toward nuclear power are a function of perceived risk, and that both attitudes and risk perceptions are a function of values, beliefs, and trust in the institutions that influence nuclear policy. Applying structural equation models to data from a U.S. national survey, we find that increased trust in the nuclear governance institutions reduces perceived risk of nuclear power and together higher trust and lower risk perceptions predict positive attitudes toward nuclear power. Trust in environmental institutions and perceived risks from global environmental problems do not predict attitudes toward nuclear power. Values do predict attitudes: individuals with traditional values have greater support for, while those with altruistic values have greater opposition to, nuclear power. Nuclear attitudes do not vary by gender, age, education, income, or political orientation, though nonwhites are more supportive than whites. These findings are consistent with, and provide an explanation for, a long series of public opinion polls showing public ambivalence toward nuclear power that persists even in the face of renewed interest for nuclear power in policy circles.

**KEY WORDS:** Nuclear attitudes; nuclear power; trust; values

## 1. INTRODUCTION

It is fit, it is safe, and it is back: nuclear power is a viable energy option again. So asserts the nuclear industry, key politicians, and other stakeholders who see a nuclear renaissance ahead.(1,2) It is fit because it is the only major source of electricity that does not produce greenhouse gases. It is safe because of nearly two decades of accident-free operations and because of a new generation[4] of "inherently safe" reactors.(3,4) It is back because the nuclear industry,[5] (7) many media sources, renewed scientific assessment

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[4] These would be generation IV reactors, the most advanced design currently under development in 12 nuclear nations, some of which produce hydrogen as a byproduct. In addition, generation III reactors are in operation in Japan, South Korea, and Taiwan.

[5] The industry supports its position by asserting that public opinion is now highly favorable to nuclear power, a conclusion based on one survey item that shows favor for nuclear power: "How important a role should nuclear energy play in meeting America's future electricity use?" Overwhelming majorities of respondents typically say nuclear should play an important role; 83% in the most recent poll in April 2005.(5) However, this finding of majority support is not new; there has been a consistent, high level of support since the question was first asked in 1985(6) and informs

(the "MIT Study"),[8,9] and a national energy policy with heavy investments in nuclear growth (Energy Policy Act of 2005) have put it back into the limelight. Coverage in the *New York Times*,[10,11] in *The Economist,*[12] in *Science* magazine,[13] as well as opinions by some leading scholars[14] and many high-ranking U.S. government officials Cheney all auger for a nuclear comeback. In view of this renewed enthusiasm, can we anticipate that a jump-start for this technology will be stalled in the United States for decades? The history of the technology provides a first context for answering this question.

### 1.1. Historical Context

From the very beginning nuclear power was (1) believed to be the cheapest form of future electricity ("too cheap to meter" proclaimed Admiral Lewis L. Strauss, then Chair of the U.S. Atomic Energy Commission in 1955), (2) was expected to replace coal as the principal fuel for electricity, and (3) was projected to provide a substantial share of the electricity needs in the advanced nations of the world. This potential was well on its way to realization with the rapid growth in the construction of new power plants in the United States and many other countries. The ever-expanding plant capacity accompanying this growth, however, had the consequence of heightening concerns for reactor safety. Indeed, the birth of the modern era of risk analysis is often dated by Chauncey Starr's classic 1969 article on "revealed" risk preferences, where he argued that public opposition was blocking what he viewed as a useful technology.[15]

What happened? A number of causal forces—accelerating costs, siting challenges, construction delays—were important. But these forces were driven to a substantial degree by an unanticipated public resistance, later deepened by the accident at Three Mile Island, Pennsylvania in 1979. It is important to note that opposition to the local siting of a nuclear plant preceded the TMI accident by nearly five years, a harbinger of the more widespread opposition that would emerge with the accident.[16][6] Subsequent research clearly demonstrated that public opposition was tied to perceptions of reactor safety, concerns about the disposal of nuclear wastes, and low levels of trust of the nuclear establishment—concerns that persist in the most recent public opinion polls.[19,20]

The key question, the one that concerns us here, is whether the renewed enthusiasm for nuclear power can overcome its history of public resistance that has persisted for decades? We address this more refined question by examining some of the most durable cognitive and cultural foundations—particularly values, beliefs, and social expectations—that underpin citizens' views of nuclear power. Operationally, we do so by refocusing a values-beliefs-norms (VBN) model of environmental commitment, developed by Stern, Dietz, and colleagues, to understand the underlying dynamics of public views toward nuclear power.[21,22]

## 2. VALUES, BELIEFS, AND TRUST

Stern *et al.*,[21,22] building on the universal human value framework of Schwartz and his colleagues,[23–25] developed a VBN model of environmental decision making that combines human values with social context variables. The VBN model deemphasizes the formal, calculative logic of the rational actor paradigm[26–28] and emphasizes the intuitive logic and the substantial ability humans display in pattern recognition and language processing.[7] When presented with a novel stimulus, such as a request to evaluate the risk associated with a technology or express their level of support for the technology, the VBN model posits that most members of the

us less about public acceptability and more about the basis for the industry's choice of question.

[6]Literally every poll since 1975 asking whether citizens would accept a nuclear power plant in their area attracted overwhelming opposition (often by margins of 2:1 or more), including the most recent poll in March 2007 showing a majority opposition of 59% compared to 40% who would find one acceptable. A seeming exception to this consistent pattern is the recent preparation by two energy consortia to seek "early site approval" for advanced design nuclear plants in the States of Illinois (Clinton), Virginia (North Ana), and Mississippi (Port Gibson). There appears to be little opposition to these intentions in Virginia and Illinois, and considerable enthusiasm for them in Mississippi. However, it is important to note that all the immediately proposed plants would be sited adjacent to currently operating plants.[17] Another apparent counterevent to the pattern of local opposition was the decision by the Tennessee Valley Authority, the nation's largest public power provider, to restart the 1,280 MW Unit One at Browns Ferry in Decatur, Alabama—which it did in May 2007. The plant had been idle for 20 years due to a failure in 1985 to meet more stringent regulations imposed after the Three Mile Island accident in 1979.[18] But, again, the restarted Unit 1 is adjacent to the two other Brown's Ferry reactors, Units 2 and 3. The remaining question then is whether it will be possible to site a new power plant in a virgin locale? Public opinion data do not provide an unequivocally affirmative answer.[19,20]

[7]The rational actor paradigm often requires individuals to engage in complicated reasoning and to make elaborate calculations.[28]

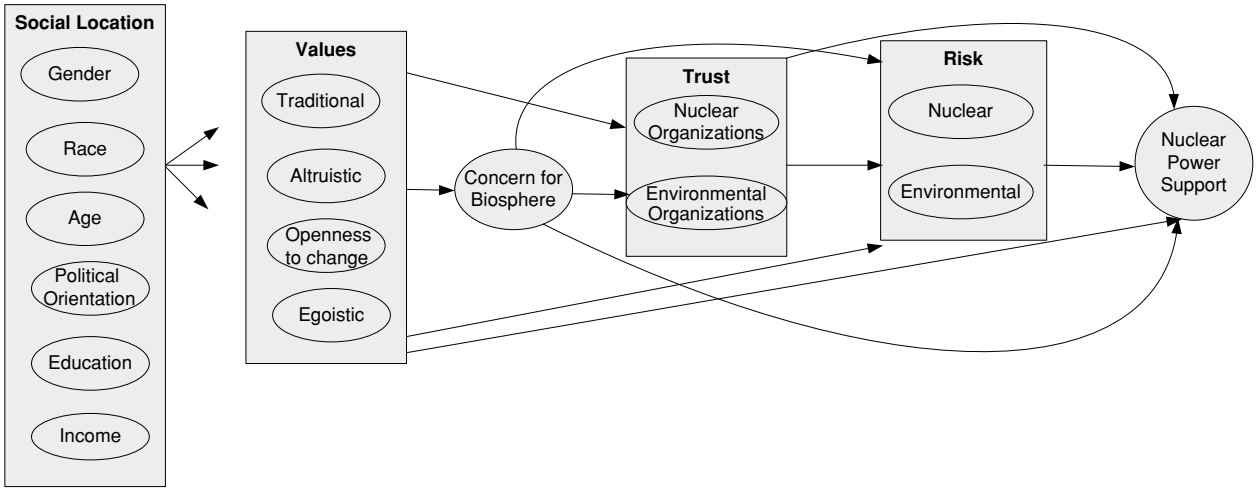


**Fig. 1.** Stern-Dietz (S-D) values-beliefs-norms model of environmental decision making applied to nuclear attitudes.

public engage in a decision process that is more social and deliberative than calculative.

The logic of the VBN model argues that, rather than following the elaborate calculations of the rational actor paradigm, it is more likely that people engage in a process of making links between the specific object in question—nuclear power in this case—and a general referent consisting of their general beliefs and values. The process can be elaborated to include a calculative logic when people have appropriate information available to them, have an opportunity to engage in an extended discussion of an issue, and have motivation to do so. But such an opportunity is rare and it is seldom permitted in the surveys and paper and pencil instruments typical of methods used in gathering the empirical evidence that underpins most risk perception literature.[27] In applying the VBN model to these issues, we have dropped consideration of both norms for action and behavioral intentions as neither of these is directly relevant to the object of our study—public concerns with and support for nuclear power. The resulting revision of the VBN model is displayed in Fig. 1.

The multistep model posits that core values are relatively stable over the course of an individual's life,[29] providing a basic referent for action, including assessing and making use of or discarding new information.[30][8] Values are linked, directly and indirectly, to the remaining components of the model. They are assumed to be a product of socialization and experience and thus are influenced by an individual's position and movement in the social structure. Altruism—a concern with the welfare of other humans and other species—has been a strong and consistent predictor of various measures of environmental concern[30,21] and in one application has been shown to influence perceptions of ecological risk.[31] High levels of altruism lead to an increase in perceived risk via people's generalized beliefs about the environment. Traditional values—assigning importance to family, patriotism, and stability—are also strong predictors of environmental concern and pro-environmental values, but their effects are directly opposite from altruism. Those with strong traditional values typically exhibit less concern about the environment and are less likely to express pro-environmental behavioral intentions. They, therefore, have more trust in the institutions that manage risk and perceive less risk from nuclear technology. In addition to altruism and traditionalism, the model includes measures of openness to change and self-interest since these are part of the value complex that has been extensively researched by Schwartz and his

[8]This is not to suggest that the public is irrational in this filtering. There are many competing sources of information and unless an issue is salient to consequential decisions for an individual, it would be irrational to spend much time assessing the strength of evidence behind competing views on, for example, the risk of accidents at nuclear power facilities or the nuclear waste transport process. In essence, we are suggesting that members of the public are informal Bayesians, so that their values and general beliefs are strong priors, and information presented in the media or in survey instruments are given limited weight in updating assessments.

colleagues.[23–25] The inclusion of these variables in the VBN model represents a logical extension of the Schwartz findings. Previous research has shown them to have little influence on environmental concern, but their effects on trust and risk perceptions have not been extensively examined, although Slimak and Dietz[31] found no link between ecological risk perceptions and self-interest, openness to change or traditional values.

In turn, values are antecedent to generalized beliefs, particularly beliefs about human relationships to the environment. The next link in the VBN model hypothesizes that those who see humans as having substantial adverse impacts on the environment will perceive greater risks for most technologies.

The importance of institutional trust—the level of confidence in those agents responsible for the management of risks—in shaping risk perceptions has attracted a considerable body of research[32–45] and is one of the most consistent findings in the risk literature. In a comprehensive review of that literature, Earle *et al.*[46] noted that while there has been a great deal of work on trust and risk, the literature has not been entirely orderly. In part, this is a result of substantial differences in theorizing trust across studies. In addition, studies differ in whether the ultimate dependent variable to be explained by trust is risk perceptions or support for technology. Earle and colleagues also argued that trust is related to values, and that our understanding of trust, especially as it relates to support for or opposition to particular technologies, can be thought of as cooperative behavior. Recent empirical evidence shows that the greater the congruency in values between individuals and institutions charged with managing risks, the greater the trust in those institutions.[41–43] Consistent with our general argument about the role of values, Poortinga and Pidgeon[31,38] (38; see also 31) found that this relationship is present for relatively new risk objects (e.g., mobile phones, GM food, genetic testing) but not present for risk objects more familiar to the public (e.g., climate change, radioactive waste). These findings are consistent with the argument that values may be most important when the public is asked about risks that are distant from their current thinking. Building on these findings our modified version of the VBN model posits direct and indirect links between core values and general beliefs or worldviews, as well as with trust, with perceived risk, and, ultimately, with attitudes toward nuclear power.

## 3. METHODS

### 3.1. Sampling Procedures

Phone interviews were conducted with 380 adults randomly selected from the U.S. population by the George Mason University Northern Virginia Survey Research Center in 1997.[9] Individuals were selected for study by random digit dialing. Within multiple-adult households, the person 18 years old or older with the most recent birthday was asked to participate. We used Dillman's[47] methods to ensure a representative sample, yielding an estimated response rate of 50.6%.

### 3.2. Description of the Sample

The demographic characteristics of the sample were generally similar to the U.S. population with the exception of gender. Compared to the U.S. population, a larger percentage of females responded to the survey (61%) compared to the population (51%).[48] Additionally, a slightly higher proportion of the sample had at least a college education compared to the U.S. population, although average household income was similar. The age and ethnic/racial composition of the sample was fairly similar to the U.S. population, although a smaller percentage of Hispanics participated (6% compared to 12% in the population).[48]

### 3.3. Measures

#### *3.3.1. Personal Characteristics*

As noted above, we collected demographic information and data on other personal characteristics. Respondents' gender, age, race (white or nonwhite), education level (in years), political orientation, and total household income were ascertained. Political orientation was measured on a 1–7 scale, from "extremely liberal" (1) to "extremely conservative" (7).

[9]While it would be useful to have more recent data, this analysis is primarily concerned with testing a basic theory of support for nuclear power, which should apply in any time period. It also provides a benchmark with which more recent data can be compared. We note below that the attitudes expressed by our sample are similar to those found in the most recent national polls. It is notable that these data were collected after the period of most intense public debate and before the current resurgence of interest in nuclear power.

*3.3.2. Scaling*

Exploratory factor analysis using principal axis and direct oblimin rotation were first performed to examine each of the scales. Then confirmatory factor analysis verified the measurement model with Chronbach's alpha as an estimate of the reliability of the scales. As presented in Table I, confirmatory factor analysis results indicated that factor loadings for each of the scales were adequate (greater than 0.4) and typically were very strong, suggesting high construct validity. We discuss the content of each scale in turn.

*3.3.3. Value Orientations*

Fifteen items from Schwartz's[49] value scale, as modified by Stern *et al.* [50] for the VBN model, were used to assess values (See Table I). Respondents were asked to "indicate how important each value is a guiding principle in your life . . ." Questions were measured on a 1–5 scale, from 1—"extremely important" to 5—"not at all important." These scales were reversed so that high scores indicate strong adherence to a value. Three items each were included to measure traditional, egoistic, and openness to change values, and six items tapped altruism.

*3.3.4. Beliefs About the Biosphere*

A seven-item subset of the New Ecological Paradigm (NEP) scale[51,52] was included in the survey (See Table I). The NEP scale measures environmental beliefs, specifically beliefs about the Earth and human-environment relationships. Response options ranged from "strongly disagree" (1) to "strongly agree" (5).

*3.3.5. Trust*

A list of 10 U.S. organizations and institutions was read to study participants, and they were asked how much trust they have in each, with responses ranging from "very little trust" (1) to "a great deal of trust" (4) (See Table I).[10] Factor analyses identified two conceptually relevant trust scales: one reflecting trust in nuclear organizations and the other trust in broader environmental organizations. The nuclear trust scale comprises trust in the Nuclear Regulatory Commission and the nuclear industry. Environmental organization trust consists of trust in the Environmental Protection Agency, national environmental groups, and university scientists. The reliability of both these scales is moderate (Cronbach's alphas of 0.65 and 0.64). Trust in the U.S. military, Congress, news media, electric utilities, and the Department of Energy are excluded from analyses as they did not load clearly on any factors, indicating that they are not perceived as a part of the nation's institutional complex by the public.

*3.3.6. Risk*

Respondents were asked to evaluate how at risk the American public is from a variety of sources. Items were adapted from the risk scales utilized by Peters and Slovic.[53] Responses ranged from "no risk" (1) to "extreme risk" (5) (See Table I). Two risk scales were created. "Nuclear risk" consists of perceived level of risk about nuclear electric power plants, nuclear waste, and nuclear weapons. "Global environmental risk" consists of depletion of ozone layer and global warming/greenhouse effect. Items measuring risk of commercial air travel, handguns, and motor vehicle accidents did not factor load. An item on coal/oil burning power plants was originally included in the global environmental risk scale, but the reliability (Cronbach's alpha) increases from 0.75 to 0.87 if the item is deleted, and the fit of the model improves with its deletion so it was not included in the scale. An item on chemical pollution in the environment loaded with ozone and climate change. However, removing the chemical pollution item did not substantially degrade the reliability of the scale, allowing for a scale with a more straightforward interpretation as "global risks."

*3.3.7. Nuclear Power Attitudes*

Four items from the Peters and Slovic[53] study were used to assess attitudes toward nuclear power (See Table I). Questions assessed the extent respondents agreed that nuclear power is an acceptable way to meet national energy needs, that nuclear power is an acceptable means to supply electricity if a community is faced with a shortage, that one would be willing to pay more taxes to avoid more nuclear power plants from being built, and that nuclear power should be relied on more for electricity because of

[10] In Earle *et al.*'s[46] terms, we have asked respondents to rate their trust in relatively specific agents involved in the nuclear power policy system.

**Table I.** Confirmatory Factor Loadings and Reliability of Scales

| Factor/Variable | Factor Loading | Alpha |
|---|---|---|
| **Traditional values**[1] | | **0.68** |
| Family security, safety for loved ones | 0.72 | |
| Honoring parents and elders, showing respect | 0.63 | |
| Self-discipline, self-restraint, resistance to temptation | 0.61 | |
| **Altruistic values**[1] | | **0.80** |
| Respecting the earth, harmony with other species | 0.75 | |
| Protecting the environment, preserving nature | 0.69 | |
| Equality, equal opportunity for all | 0.67 | |
| Social justice, correcting injustice, care for the weak | 0.63 | |
| Unity with nature, fitting into nature | 0.61 | |
| A world at peace, free of war and conflict | 0.59 | |
| **Openness to change values**[1] | | **0.67** |
| An exciting life, stimulating experiences | 0.68 | |
| Curious, interested in everything, exploring | 0.65 | |
| A varied life, filled with challenge, novelty, and change | 0.57 | |
| **Egoistic values**[1] | | **0.54** |
| Influential, having an impact on people and events | 0.79 | |
| Authority, the right to lead or command | 0.47 | |
| Wealth, material possessions, money | 0.37 | |
| **New ecological paradigm**[1] | | **0.74** |
| If things continue on their present course, we will soon experience a major ecological catastrophe | 0.71 | |
| The balance of nature is very delicate and easily upset | 0.69 | |
| The earth is like a spaceship with very limited room and resources | 0.62 | |
| Humans are severely abusing the environment | 0.58 | |
| The balance of nature is strong enough to cope with the impacts of modern industrial nations | 0.40 | |
| The so-called ecological crisis facing humankind has been greatly exaggerated[2] | 0.33 | |
| Human ingenuity will ensure that we do NOT make the earth unlivable[2] | 0.28 | |
| **Nuclear trust** | | **0.65** |
| The nuclear industry | 0.72 | |
| The Nuclear Regulatory Commission | 0.63 | |
| **Environmental trust** | | **0.64** |
| Environmental Protection Agency | 0.80 | |
| National environmental groups | 0.56 | |
| University scientists | 0.49 | |
| **Nuclear risk** | | **0.74** |
| Nuclear electric power plants | 0.82 | |
| Nuclear waste | 0.66 | |
| Nuclear weapons | 0.62 | |
| **Global environmental risk** | | **0.87** |
| Depletion of ozone layer | 0.89 | |
| Global warming/greenhouse effect | 0.87 | |
| **Nuclear attitudes** | | **0.71** |
| If your community was faced with a potential shortage of electricity, constructing a new nuclear power plant would be one acceptable means of supplying that electricity | 0.76 | |
| In light of health concerns about acid rain, damage to the ozone layer, and climate change associated with the burning of coal and oil, America should rely more heavily on nuclear power to meet its future electricity needs | 0.66 | |
| I would be willing to pay a significant increase in my taxes to prevent the possibility of any more nuclear power plants being built[2] | 0.47 | |
| Nuclear power is not an acceptable approach for meeting the nation's energy needs[2] | 0.45 | |

[1]To reduce the number of parameters to be estimated with SEM, only the overall mean score of these scales were included in the final model, so these CFA results were run separately.
[2]Response options for this item were reverse coded.

environmental problems.[11] Response options ranged from "strongly disagree" (1) to "strongly agree" (5). The reliability of this scale is relatively good (Cronbach's alpha = 0.71).

### 3.4. Data Analysis

The overall VBN model was tested with structural equation modeling (SEM). We used AMOS[54] to estimate parameters. Modification indices did not suggest that the addition of any parameters would significantly improve the fit of the model, so none were added. To reduce the number of parameters to be estimated, the model only includes the overall summary scales for the four value scales and the NEP scale, rather than the scale's individual items since their measurement properties have been well established. The resulting model met the criteria of conventional measures of fit.[12]

## 4. RESULTS

### 4.1. Nuclear Attitudes

Consistent[13] with some of the most recent national polls,[19,20,55] the average score on the nuclear attitudes scale is in the mid-range (mean = 3.2, range = 1–5), indicating a continuing ambivalence toward the technology. Forty-two percent of respondents agreed that if there were a shortage of electricity, nuclear power would be an acceptable way of supplying electricity. Just less than one-third of respondents disagreed that nuclear power would be acceptable in the case of shortages and a similar percentage said they are unsure. The percentages are similar for the item concerning nuclear power's acceptability as a way to meet national energy needs. Only one-quarter of study participants said they are willing to pay more taxes to prevent more nuclear power plants from being built, while a 53% majority are unwilling to pay additional taxes. In terms of using nuclear power for electricity in light of environmental and health problems associated with coal and oil usage, respondents were evenly divided, with 36% opposed to this option and 34% in favor of it.

### 4.2. Risk

Consistent with previous research,[56] respondents believed that of the five nuclear and environmental dangers assessed, nuclear waste[14] and nuclear weapons pose the greatest public risk (with over 70% of respondents saying each poses serious or extensive risk). Sixty percent said the ozone layer poses a serious or extensive public risk, while a plurality of 43% believes that nuclear electric power and global warming are a serious risk. The nuclear and global environmental risk scales are moderately correlated ($r = 0.46$).

### 4.3. Trust

Respondents, on average, had somewhat more trust in environmental institutions than in nuclear institutions (2.7 versus 2.2 mean scale values). Consistent with previous research, the greatest amount of trust is vested in university scientists (74% quite a lot to a great deal of trust), followed by the Environmental Protection Agency (57%) and national environmental groups (54%). Thirty-seven percent of study participants had a great deal or quite a lot of trust in the Nuclear Regulatory Commission, and 30% had similar levels of support for the nuclear industry. Interestingly, the two trust scales, environmental and nuclear, are very weakly correlated ($r = 0.01$).

### 4.4. Multivariate Results

The structural equation model (SEM)—consisting of demographics, values, environmental concern, institutional trust, and risk—achieved a good fit (CFI = 0.943; RMSEA = 0.045, 90% CI = 0.036–0.053; TLI = 0.888; chi square = 291.324). The estimated coefficients, standardized and unstandardized, are presented in Table II.

[11] A fifth item, "I would be in favor of nuclear power if the problem of disposal of nuclear waste could be solved once and for all," loaded strongly onto the nuclear support factor. Since this item relates to waste, whereas the other items do not, it was excluded from the final model. When the multivariate model is run with it added to the scale of nuclear support, none of the substantive findings change.

[12] The comparative fit index (CFI), root mean square error of approximation (RMSEA) and its confidence interval, and Tucker-Lewis index (TLI) were used to assess the fit of the model. CFI and TLI values greater than 0.9 and a RMSEA value of less than 0.5 with a small confidence band indicate a good fitting model.

[13] Descriptive statistics are available from the authors on request.

[14] An in-depth examination of the factors that underlie nuclear wastes at weapons sites shows that publics are most concerned about radioactive wastes leaking into local streams and drinking water.[33]

**Table II.** Multivariate Results—Unstandardized (Standardized) Coefficients

| | Outcome | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Predict | Nuc Supp | Env Risk | Nuclear Risk | Env Trust | Nuc Trust | NEP | Tradition | Altruist | Openness | Egoistic |
| Female | −0.01 (−0.00) | 0.33(0.15)** | 0.17 (0.08) | −0.04 (−0.05) | −0.20 (−0.16)* | 0.03 (0.02) | 0.12 (0.10)* | 0.13 (0.10) (p = 0.060) | −0.10(−0.06) | −0.20(−0.11)* |
| White | −0.31(−0.13)* | −0.29(−0.10)* | −0.20 (−0.08) | 0.00 (0.00) | 0.25 (0.16)* | 0.09 (0.05) | 0.16 (0.12)* | 0.09 (0.06) | 0.11(0.05) | −0.31(−0.15)** |
| Age | −0.00 (−.07) | −0.00 (−.03) | 0.00 (0.02) | −0.00 (−0.11) (p = 0.063) | 0.00 (−0.02) | −0.01(−0.14)** | −0.00 (−0.07) | −0.00 (−0.06) | −0.00(−0.07) | 0.00(0.00) |
| Pol orien | −0.01 (−0.01) | −0.04 (−0.05) | 0.03 (0.05) | −0.01 (−0.03) | 0.03 (0.07) | −0.04 (−0.08) | 0.02 (0.04) | −0.09(−0.20)*** | −0.06(−0.10) (p = 0.060) | 0.04(0.07) |
| Educ | −0.03 (−0.09) | −0.02 (−0.04) | −0.05(−0.14)* | 0.00 (0.02) | 0.01 (0.05) | −0.02 (−0.06) | −0.01 (−0.06) | −0.02(−0.10) | 0.04(0.12)* | −0.03(−0.11) (p = 0.052) |
| Income | −0.05 (−0.08) | −0.03 (−0.04) | −0.04 (−0.06) | −0.01 (−0.04) | 0.02 (0.04) | 0.06 (0.10) | 0.03 (0.08) | −0.03(−0.06) | −0.00(−0.01) | −0.00(−0.00) |
| Tradition | 0.24 (0.13)* | −0.24(−0.12)* | −0.14 (−0.07) | −0.09 (−0.11) | 0.04 (0.04) | −0.26(−0.19)** | – | – | – | – |
| Altruistic | −0.31(−0.20)* | 0.43(0.25)*** | 0.25 (0.16) | 0.26(0.38)*** | −0.03 (−0.04) | 0.51(0.43)*** | – | – | – | – |
| Open ch | 0.10 (0.08) | 0.06 (0.05) | 0.02 (0.02) | −0.04 (−0.08) | 0.06 (0.09) | −0.04 (−0.04) | – | – | – | – |
| Self-int | 0.08 (0.07) | −0.05 (−0.04) | 0.05 (0.05) | 0.06 (0.12) | −0.05 (−0.06) | −0.12(−0.13)* | – | – | – | – |
| NEP | −0.03 (−0.03) | 0.53(0.37)*** | −0.05 (−0.03) | 0.12(0.20)** | −0.26(−0.33)*** | – | – | – | – | – |
| Env trust | −0.18 (−0.08) | −0.01 (−0.00) | 0.34 (0.15) | – | – | – | – | – | – | – |
| Nuc trust | 0.83(0.52)** | −0.17 (−0.10) | −1.04(−0.63)*** | – | – | – | – | – | – | – |
| Env risk | 0.13 (0.14) | – | – | – | – | – | – | – | – | – |
| Nuc risk | −0.41(−0.43)** | – | – | – | – | – | – | – | – | – |
| $MR^2$ | **0.70** | **0.37** | **0.57** | **0.23** | **0.21** | **0.17** | **0.04** | **0.08** | **0.04** | **0.05** |

*$p < 0.05$, **$p < 0.01$, ***$p < 0.001$.

### 4.5. Predictors of Attitudes Toward Nuclear Power

Table II presents all of the unstandardized and standardized coefficients for the estimated VBN model. As hypothesized, greater trust in nuclear organizations lowers perceived risk of nuclear power, and together trust and risk strongly predict levels of support for nuclear power (see Table II). Contrary to expectations, greater trust in environmental institutions and lower perceived global environmental risk are not predictive of positive nuclear attitudes. Values, as predicted, influence nuclear attitudes in opposite ways: individuals who are more traditional in their beliefs have greater support, while those who are more altruistic have greater opposition to nuclear power. Neither openness to change, nor self-interest, nor the NEP-measured concern for the biosphere are directly associated with nuclear attitudes. In terms of social location, nonwhites showed higher levels of support for nuclear power than whites. As repeatedly shown in previous research, the principal demographic finding is a nonfinding:[16,56] nuclear attitudes neither vary by gender, by age, by education, by income, nor by political orientation, and there was no gender-ethnicity interaction.

### 4.6. Predictors of Perceived Nuclear Risk

Less trust in nuclear organizations and lower education predict greater perceived risk of nuclear power. Therefore, education is indirectly associated with nuclear attitudes via risk, and trust in nuclear institutions has both direct effects and indirect effects on nuclear attitudes via nuclear risk. Values, other social location variables, concern for the biosphere, and environmental trust are not predictive directly of perceived nuclear power risks. However, gender, age, political orientation, and concern for the biosphere influence perceived risk indirectly through judgments about nuclear institutions (described below).

### 4.7. Predictors of Perceived Global Environmental Risk

Individuals low on traditional values, high on altruism, and high on the NEP scale tend to have greater perceived global environmental risk. Women see greater global environmental risks than men and the same holds true of nonwhites versus whites. By including dummy variables for the gender and ethnicity interaction, we found that white males perceive lower global environmental risks than other groups, a finding consistent with some previous work on environmental concern.[57,58] Trust, openness to change, and egoistic orientations, income, education, age, and political orientation do not affect perceived global environmental risk.

### 4.8. Predictors of Nuclear Trust

Individuals with lower scores on the NEP scale (i.e., with less concern for the biosphere) have greater trust in nuclear organizations. The test for a statistical interaction between gender and race revealed that white males have higher levels of trust in nuclear organizations than do either nonwhite males or females. Values, age, political orientation, education, and income do not predict trust in nuclear organizations.

### 4.9. Predictors of Environmental Trust

Individuals who are more altruistic and have higher scores on the NEP scale express greater trust in environmental organizations. It is worth noting that the NEP scale has positive effects on environmental trust but negative effects on nuclear trust. A positive relationship between age and trust in environmental organizations, where the young are more trusting than other age groups, approaches statistical significance ($p = 0.063$). Other social location variables and values do not correlate with environmental trust.

### 4.10. Total Effects

The SEM showing only significant paths is presented as Fig. 2. Table III presents the direct, indirect, and total effects for the paths in Fig. 2. The direct, indirect, and total effects are computed by AMOS using standardized coefficients. As is obvious, the resulting, trimmed model is considerably simpler than the theoretical figure offered in Fig. 1 because a number of hypothesized influences are not supported by our data analysis.

Attitudes toward nuclear power are driven directly by the perceived risk of the technology and the levels of trust in the institutions responsible for managing it. As predicted by the VBN model, values clearly influence nuclear attitudes both directly and indirectly when risk perception and trust are controlled. Earle *et al.*[46] have argued that risk perception is markedly influenced by the institutions,

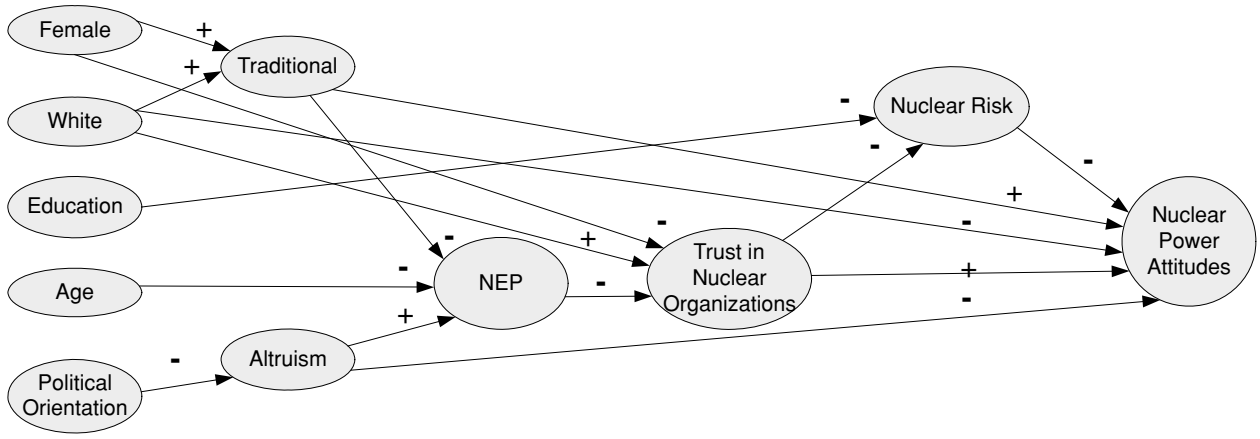


**Fig. 2.** Reduced structural equation model (SEM) version of the Stern-Dietz (S-D) model: Statistically significant causal paths.

such as communities, with which citizens identify. Our results are consistent with that argument; those whose values incorporate concern for other humans, for other species, and for the biosphere more generally are less supportive of nuclear power even when controlling for their level of trust in the institutions that manage nuclear power and for their risk perceptions. In contrast, those who hold to traditional values are more supportive of nuclear power, suggesting that these values shape their attitudes toward nuclear power in the opposite way. It is worth noting that the U.S. anti-nuclear movement of the 1970s criticized not only the technological risks of nuclear power, but also the centralized and high security policies that would accompany nuclear power. One writer of those times summarized the argument this way: "if you accept nuclear power plants, you also accept a technoscientific-industrial-military elite. Without these people in charge, you could not have nuclear power."[59] Historically, therefore, risk was not the only factor driving opposition to nuclear power for many citizens in those early days, and this still appears to be of considerable importance now.

Perceived nuclear risk is a direct function of trust and respondent education, while trust in the nuclear industry and regulatory agencies is a function of generalized beliefs or worldview about human impacts on the environment. We also find the oft-reported outlier effects of white males,[57,58] but rather than a direct effect on risk, the typical finding in previous work, we find the effects to be indirect through environmental concern and trust. Being a white male has a direct effect on trust—a link not examined in previous studies on gender, race, and risk[15]—which, in turn, shapes their nuclear attitudes. Again, this seems consistent with Earle *et al.*'s[46] arguments about communities of shared values and beliefs that are the source of risk perceptions and, in this case, trust.

**Table III.** Direct, Indirect, and Total Effects of Model Variables on Nuclear Attitudes (Standardized Coefficients)

| | Direct Effects | Indirect Effects | Total Effects |
|---|---|---|---|
| Female | −0.00 | −0.16 | −0.16 |
| White | −0.13 | 0.14 | 0.02 |
| Age | −0.07 | 0.02 | −0.05 |
| Political orientation | −0.01 | 0.13 | 0.13 |
| Education | −0.09 | 0.15 | 0.07 |
| Income | −0.08 | 0.07 | −0.01 |
| Traditional values | 0.13 | 0.11 | 0.24 |
| Altruistic values | −0.20 | −0.22 | −0.41 |
| Openness to change | 0.08 | 0.09 | 0.17 |
| Self-interest | 0.07 | −0.06 | 0.01 |
| NEP | −0.03 | −0.22 | −0.24 |
| Environmental trust | −0.08 | −0.06 | −0.14 |
| Nuclear trust | 0.52 | 0.26 | 0.78 |
| Environmental risk | 0.14 | – | 0.14 |
| Nuclear risk | −0.43 | – | −0.43 |

Risk from global environmental problems does not influence trust, but is a function of generalized beliefs, values, and background. Altruists and those concerned with anthropogenic harm to the biosphere

[15]Being white has a negative direct effect on support, but this is more than balanced by the positive indirect effects through traditional values and trust in the institutions that manage nuclear power.

may be thought of as a socially committed community concerned with climate change and ozone depletion, while traditionalists reject such concerns. However, trust in environmental organizations and regulatory agencies is not linked to perceived risk. Unlike the nuclear power infrastructure, these institutions are not responsible for nuclear problems but, rather, in some cases responding to them. This demarcation in institutional roles may account for this difference; even if environmental institutions are trusted, they have limited power to prevent nuclear risks from manifesting. Trust in environmental institutions is a function of altruism and general beliefs, consistent with the argument that there is a community of concern and with the predictions of the VBN model.

The importance of trust can be assessed by considering both its direct and indirect effects on support for nuclear power. The direct effect is just the estimated coefficient for trust as a predictor of support, net of other variables—0.52 in standard deviation units. That is, for every standard deviation increase in trust we would expect nuclear support to increase by half a standard deviation. But there is also an indirect effect of trust through risk perception. This is estimated as the product of the coefficient linking perceived nuclear risk to support (−0.43) and the coefficient linking trust in nuclear management institutions to perceived risk (−0.63). The indirect effect is thus 0.27. Adding this to the direct effect gives a total effect of trust of 0.78. That is, a standard deviation increase in trust would lead to a 0.79 standard deviation increase in nuclear support.

Values and general beliefs also have substantial indirect effects on nuclear attitudes. For traditional beliefs, the direct effect is 0.13, the indirect effect is 0.11 for a total effect of 0.24, while for altruism the direct effect is −0.20 and the indirect effect −0.22, for a total effect of −0.41. The direct effect of the NEP on nuclear views is small (−0.03) but the total effect is moderate (−0.24).

## 5. DISCUSSION

We began our investigation with the question of whether or not happy days are here again for nuclear power. The most recently available national opinion data on expanding the number of nuclear power plants reveals an ambivalent American public. From 2001 to 2003 polls show a slight (51%) to solid majority (60%) opposed to this option.[19] Recent Gallup polls,[20] however, show a slightly positive attitude, where: in 2004 54% favored nuclear compared to 43% opposed; in 2006, 55% favored while 40% opposed; and in 2007, 50% favored while 46% opposed (although this barely exceeds statistical significance). Moreover, the most compelling *raison d'etre* for reviving nuclear power, as a solution to global warming, has yet to attract widespread support.[16]

Despite this considerable opposition, the American public supports nuclear power for the generation of electricity in the abstract: in the most recent national poll 53% favor this option,[19,20] a finding consistent with the plurality support (42%) that we found here, although the majority of our study's respondents either oppose (28%) this option or are unsure (30%). This evidence together with the data on persistent majority opposition to local plant sittings, as described in footnote 3, is not encouraging to the widely claimed revival of nuclear power.

Our survey was designed to unpack global attitudes toward nuclear power by examining their underlying cognitive, cultural, and social elements. The results from our SEM estimates sustain previous findings,[40,45,61] showing the importance of institutional trust on risk perceptions and the importance of both in shaping attitudes toward risky technologies, such as nuclear power. The direct effect of trust is slightly stronger (0.52) than the direct effect of perceived nuclear risk (0.43), and the total effects are substantially larger. Even controlling for trust, risk perceptions, and the NEP, values maintain a substantial direct effect on support for nuclear power. When we turn to the immediate antecedents of perceived nuclear risk, we find that trust dominates and education is the only other independent variable that has a significant direct effect.

In general, our results extend the cumulative findings in the literature on the connection between institutional trust, risk perceptions, and attitudes toward risk technologies. Importantly, however, they deepen our understanding of the dynamics of technological decisions by demonstrating the key importance of values—both directly and indirectly via environmental worldviews, trust in nuclear organizations, and perceptions of risk. Not only do these results

[16] Public concerns about global warming are at levels rare for attitudes about any issue.[60] However an April 2007 poll showed despite its overwhelming concern for global warming the American public is not convinced that nuclear power is an acceptable solution. When a March 2007 Gallup poll asked whether respondents would support "the construction of a nuclear plant within 20 miles of your home," 64% said it is something we should not be doing.[20]

sustain the prediction of the VBN model, but they also refine our understanding of attitudes toward nuclear power by distinguishing between traditional values that increase risk tolerance from socially conscious values that decrease tolerance.

## 6. CONCLUSIONS

A proper interpretation of our results requires an appreciation of the "plasticity" of variables, by which we mean the speed with which a given variable can change in any direction and the possible range of that change.[62] Longitudinal data on nuclear attitudes over decades show them to be asymmetrically plastic. It is relatively easy to increase nuclear opposition with negative events, such as public protests or accidents such as Three Mile Island, but very difficult to increase nuclear support, even after long periods of safe operations.[6] Hence, whether a new generation of safe reactors, or a burst of enthusiasm from the nuclear industry, or national policy and financial support can redirect nuclear attitudes to be supportive of the technology is highly problematic. As for trust, the risk perception literature has been dominated by the assertion that trust is fragile—once broken it is hard to regain.[40,44] Our data reaffirm that those who believe that nuclear power is an essential part of America's future energy supply will need to devote as much attention to institutional design and performance as they do to reactor design if they hope to win public support. Our results, along with the other data reviewed here, suggest that public attitudes toward nuclear power, while considerably less negative than in the recent past and trending slightly positive, are not yet reflective of the exuberance of those predicting an early renaissance in commercial nuclear power.

The VBN model, supported in part by our results, frames and summarizes the dynamics of what shapes nuclear attitudes. It shows that the individual decisionmaker is neither an isolated, cold, calculating maximizer of the rational actor paradigm, nor is the "cognitive cripple" ruled by incoherent thinking once believed in the psychology of risk. Instead, the decisionmaker exhibits a rich combination of cognitive insight, social and emotional intelligence,[63] and cultural awareness, all anchored by fundamental values showing concern for others and the environment.

To the extent that an enhanced reliance on nuclear power is or can become technologically, economically, and environmentally viable, it will require not only a more robust understanding of the underlying drivers of public attitudes, values, and perceptions about nuclear power but also active assimilation of that understanding into public policy and institutional design.

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